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Abstract

In recent years, the progress of information and communication technologies such as cloud computing is remarkable. The storage system of electricity such as NAS and redox flow batteries is also being made a large progress. Therefore, in this study, we would like to analyze economics of smart community connecting the commercial and residential sectors using photovoltaic cell and electricity storage system under various conditions including cost improvements.

The electricity storage system has the largest problem of economics in smart community connecting the commercial and residential sectors. Under the present cost conditions on the electricity storage system, total economics of smart community become worse, as the size of electricity storage system becomes larger.

For the sake of expanding smart community connecting the commercial and residential sectors, the cost reduction of smart facilities such as photovoltaic cell and electricity storage system is quite important as a future subject. Of these, the cost reduction of the electricity storage system would play an essential role particularly from the viewpoint of technology innovation.

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Introduction

Recently Japanese Government has determined the new target of GHGs reduction to achieve 26% reduction from the emission level in 2013 up to 2030. Because of the East Japan great earthquake and Fukushima nuclear accident, the discussions on the reduction target of GHGs were wandered so largely in recent 4 or 5 years and finally converged into the above-mentioned conclusion. However, basically in the long-run, Japan must intensify her GHGs reduction measures, because she already agreed 50% (or 80%) reduction of GHGs in 2050 in the past several Summits etc. In addition, the Paris agreement on post Kyoto GHGs reduction was finally approved by many countries including various developing countries in December 2015.

The GHGs emissions in Japan have increased to the large extent from the 1990 level (the base level in Kyoto Protocol), though the first commitment period of Kyoto Protocol finished in 2012. Especially, the continuous increases in GHGs emission in the commercial and residential sectors were so largely influenced to the whole increases in Japan.

In recent years, the progress of information and communication technologies such as cloud computing is so remarkable. The storage system of electricity such as NAS battery and redox flow battery is also being made a large progress. Therefore, in this study, we would like to analyze economics of smart community connecting the commercial and residential sectors using photovoltaic (PV) cell and electricity storage system (ESS) under various conditions including cost improvements. We also would like to discuss the future subjects of smart community.

Methods

In this study, we made economics simulations on the introduction of smart facilities such as photovoltaic cell and electricity storage system as important functions of smart community connecting the commercial and residential sectors. Figure 1 shows the electricity supply and demand patterns in the commercial and residential sectors and the PV electricity supply pattern in Tokyo area for January, April, July and October used in this study.

First of all, the average electricity demand pattern in the commercial and residential sectors was estimated by month based on the METI survey report [1], EDMC survey data [2] and Cogeneration Comprehensive Manual [3]. We also surveyed present situations on photovoltaic cell, and electricity storage system on the basis of NEDO and METI reports [4, 5]. The average daily pattern of PV electricity generation was estimated by month using NEDO Sunshine Database [6].

The number of households in the residential sector was assumed to be 15,000 and the total floor area in the commercial sector was also assumed to be 300,000 m². The capacity of photovoltaic (PV) cell for each house in the residential sector was assumed at 4 kW. The number of households installed a photovoltaic (PV) panel

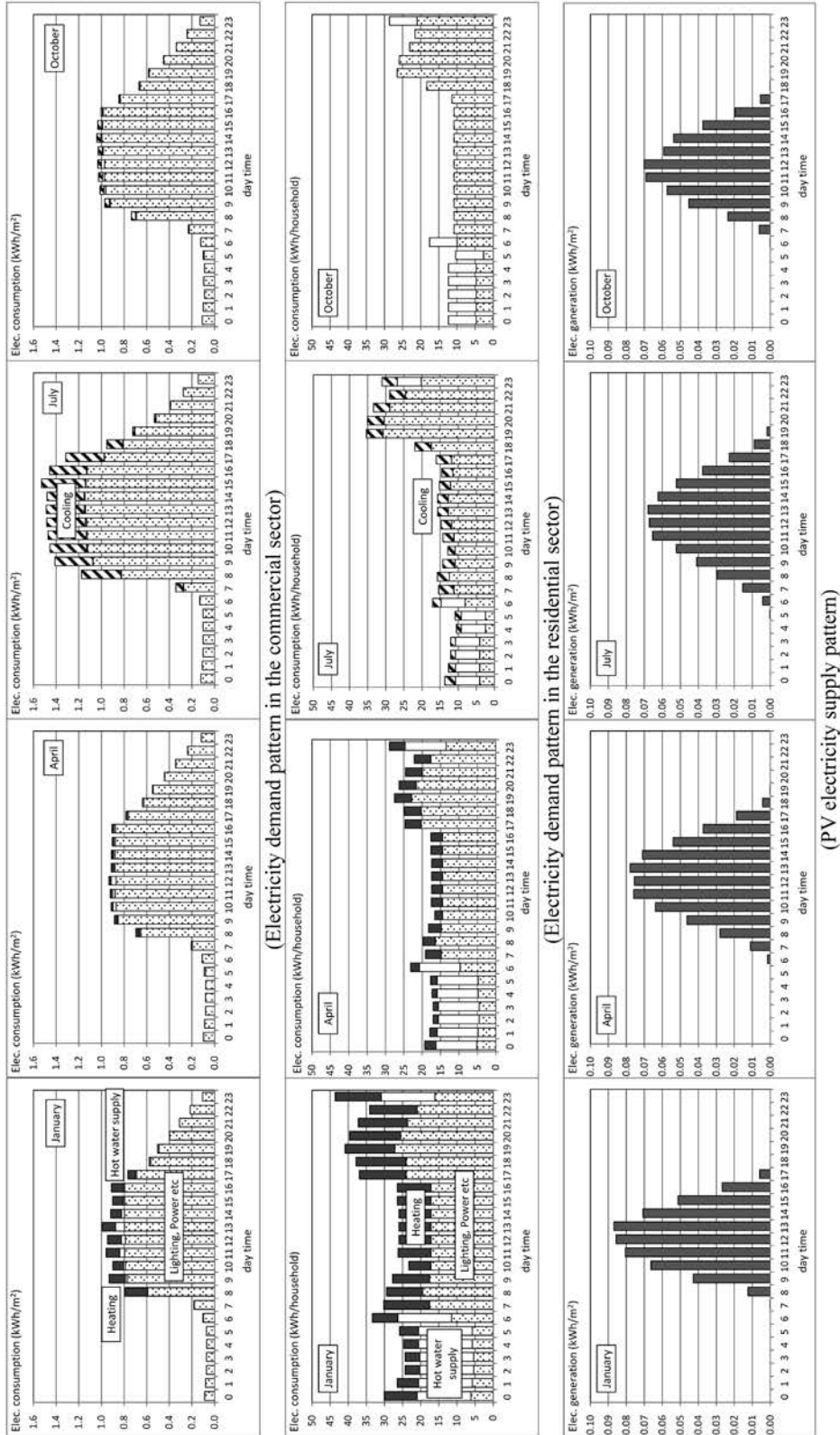


Fig. 1 Electricity supply demand patterns and PV electricity supply patterns assumed in this study

was changed from 0 to 15,000 by every 2,500 in the present simulation. The capacity of photovoltaic (PV) cell in the commercial sector was also changed from 0 MW to 240 MW every 40 MW.

The capacity of electricity storage system (ESS) was also changed from 0 kWh to 240,000 kWh by every 40,000 kWh in the present simulation. In the simulation, the charging of electricity storage system was made from 0:00 to 6:00 for cheap purchased electricity in midnight if necessary and from 7:00 to 18:00 for surplus PV electricity, and the discharging of electricity storage system is made in necessary hours judging from electricity consumption.

First, the generated PV electricity in the commercial and residential sectors was used for the supply to its own consumption. Second, the remaining generated PV electricity was used for the direct supply to the consumption in the other sector if necessary. Third, the further remaining generated PV electricity was charged into the electricity storage system for necessary discharging. Forth, the final remaining generated PV electricity was sold to power companies using FIT system.

The assumptions on photovoltaic (PV) cell made in this study were as follows. The cost of photovoltaic cell was assumed to be 350,000 Yen/kW for the residential sector (small-scale) and 300,000 Yen/kW for the commercial sector (large-scale or mega solar) by checking various surveyed data on photovoltaic cells. The cost of electricity storage system was assumed to be 150,000 Yen/kWh by checking various surveyed data on electricity storage system.

According to the Photovoltaic Expansion Center, the subsidy system to the photovoltaic (PV) cell for the residential sector was as follows: (1) the subsidy from Japanese government is 20,000 Yen/kW if the cost of concerned PV system for subsidy is 410,000 Yen/kW or less and is 15,000 Yen/kW if the cost of concerned PV system for subsidy is between 410,000 and 500,000 Yen/kW, and (2) As for the subsidy from the local government, in the case of the Metropolis of Tokyo, there is no subsidy from the Metropolis but subsidy of average 50,000 Yen/kW with upper limit of average 200,000 Yen.

This subsidy system described above was assumed for the PV introduction in the residential sector in this study. The one third of initial cost of electricity storage system and photovoltaic (PV) cell introduced in the commercial sector was also assumed to be subsidized by the Government. These subsidy conditions to the photovoltaic (PV) cell mentioned above was adopted in this simulation.

In addition, the various differences of electricity charge between daytime and night were assumed as follows. In this study, several cases of the electricity charges different from hour by hour were assumed under the condition that the total electricity charge revenues to standard electricity consumption of average household based on the existing survey would be the same (neutral) among plural cases.

Final surplus electricity generated by photovoltaic cell was assumed to be sold at FIT (Feed in tariff) price of 37

Yen/kWh for the residential sector and the 32 Yen/kWh for the commercial sector (actual value in fiscal 2013).

The economics of the introduction of smart facilities is judged from the simple payback years which is calculated by dividing the net initial cost (excluding cost covered by the subsidy) of necessary facilities by the annual profit brought by the reduction of purchased electricity and the sales of final remaining surplus PV electricity under the FIT system .

Results

(1) Changes in daily electricity supply-demand pattern in the commercial, residential and storage sectors

Figure 2 - 4 show changes in daily electricity supply-demand by the introduction of photovoltaic (PV) cell system (4 kW for 0 or 15,000 houses in the residential sector and 0 or 60 MW in the commercial sector) and electricity storage system (240 MWh) as for the winter season (January), the intermediate season (April) and the summer season (July), respectively.

In the case of no PV introduction both in residential and commercial sectors, the cheap electricity purchased from the power company in midnight and before dawn is fully charged into the electricity storage system. Especially in January, the purchased electricity from the power company is charged into the electricity storage system.

As shown in Figs. 2 and 4 in the case of no PV introduction either in residential or commercial sector, the surplus PV electricity is directly supplied to the other sector in day time and the remaining surplus PV electricity charged into the storage system for discharging in evening or night time. In the case of PV 60 MW both in the residential and commercial sectors, the remaining surplus PV electricity is sold to the power company.

(2) Changes in annual electricity supplies and economics of smart community under various capacity conditions

The estimated results on changes in economics of smart community using photovoltaic cell and electricity storage system under various capacity conditions are shown in Figs. 5 and 6. The increase on the capacity of electricity storage system is quite important to reduce purchased electricity by using photovoltaic cell effectively in the smart community connecting the commercial and residential sectors. Based on these results in this study, the purchased electricity could be largely reduced if the size of electricity storage system becomes larger.

However, under the present cost conditions such as the electricity storage cost at 150,000 Yen/kWh, the economics of smart community connecting the commercial and residential sectors become worse rapidly, judging from the payback years. It is considered that the infiltration of smart community connecting the commercial and residential sectors would be quite difficult in the present stage, because the cost burden of

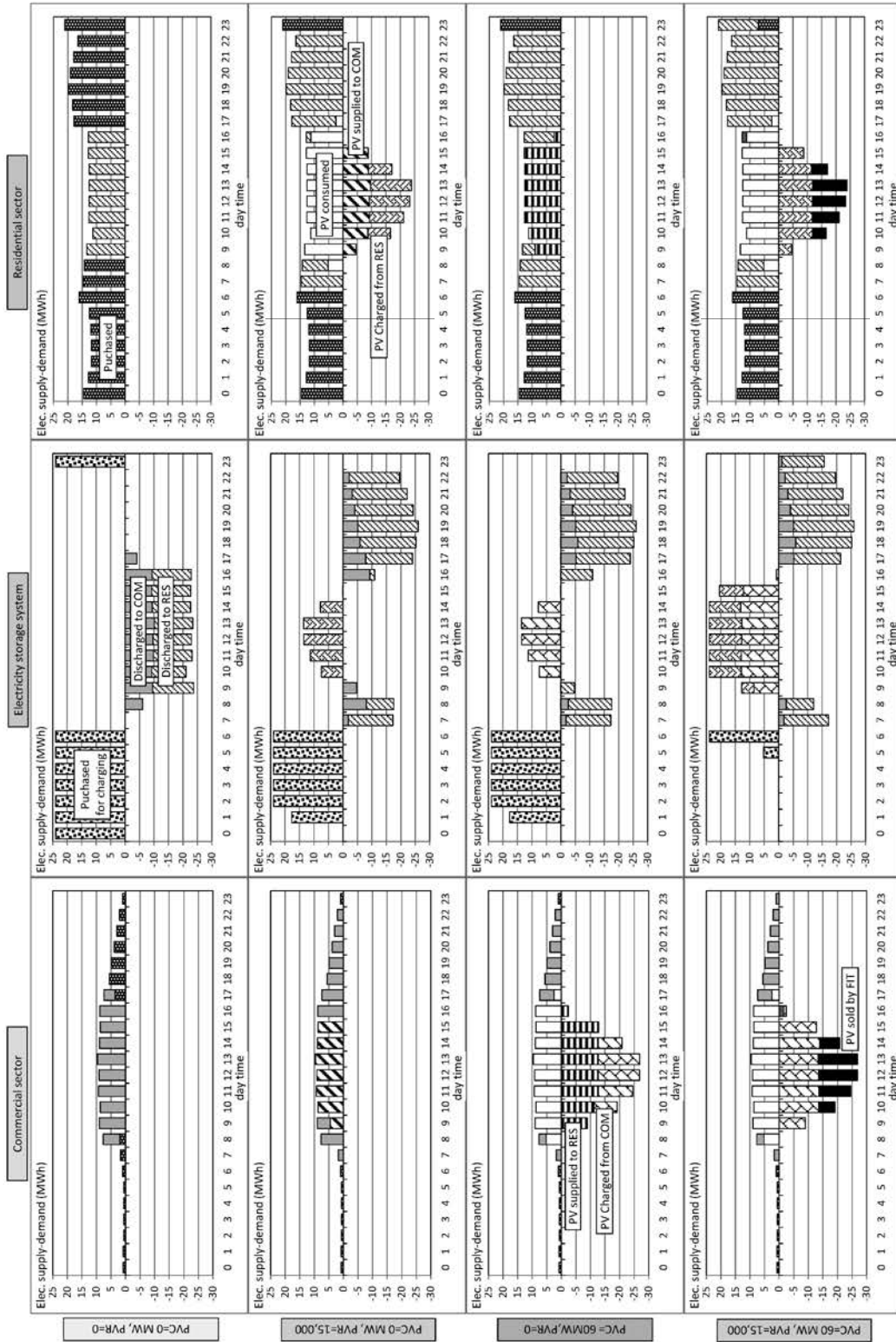


Fig. 2 Changes in daily electricity supply-demand patterns by the introduction of PV system in winter season (January)

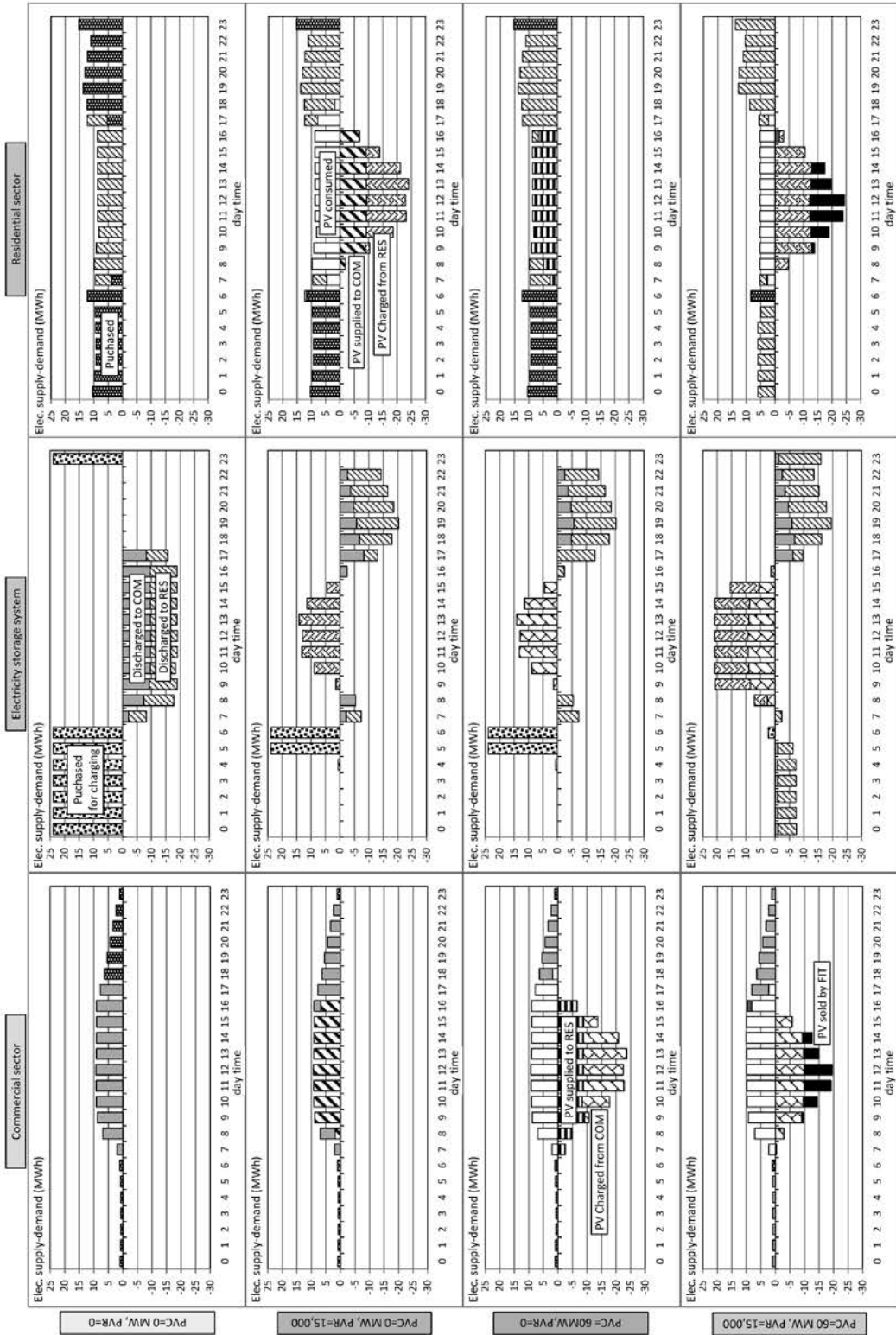


Fig. 3 Changes in daily electricity supply-demand patterns by the introduction of PV system in intermediate season (April)

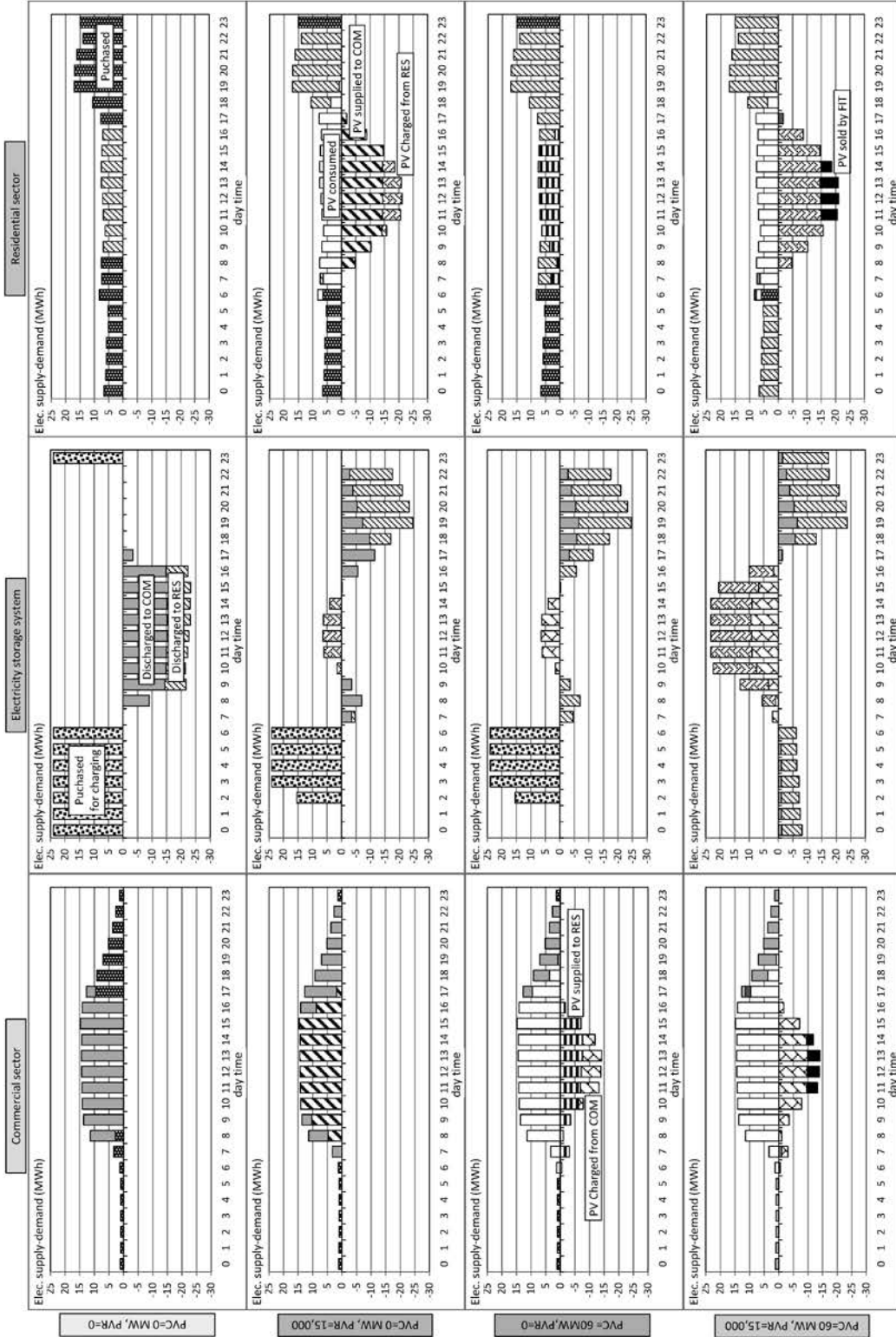
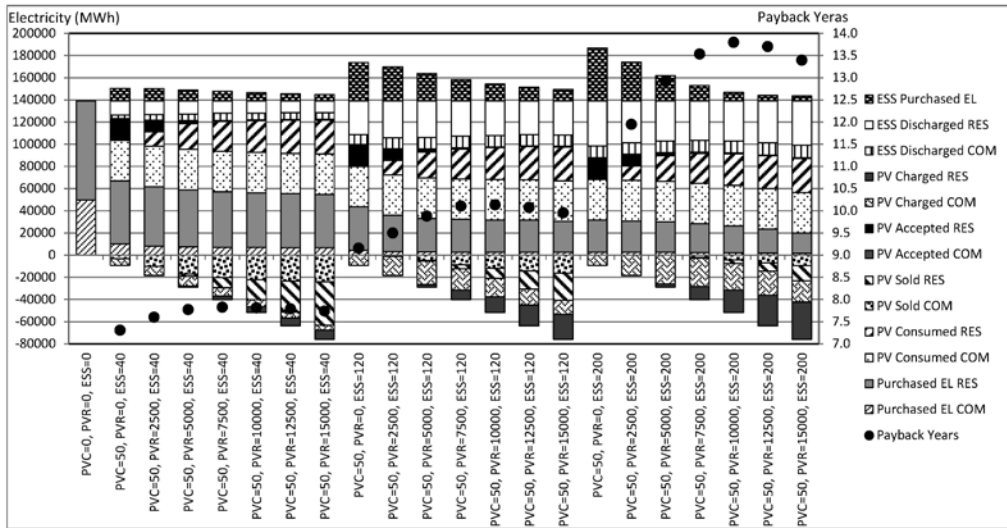
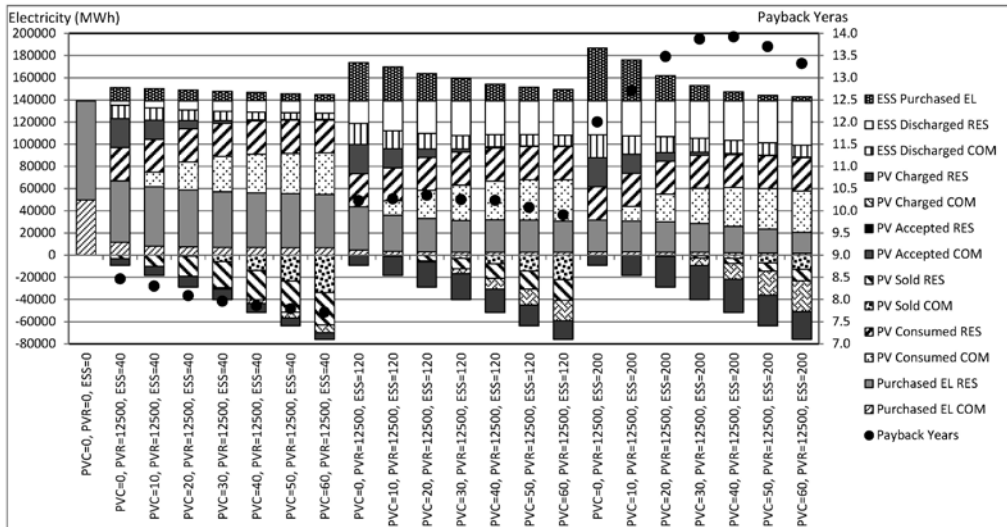


Fig. 4 Changes in daily electricity supply-demand patterns by the introduction of PV system in summer season (July)



(Note) RES: Residential sector, COM: Commercial sector, EL: Electricity, PV: Photovoltaic cell and ESS: Electricity storage system.

Fig. 5 Changes in electricity supply-demand in the smart community and changes in economics by the installed PV capacity in the residential sector



(Note) RES: Residential sector, COM: Commercial sector, EL: Electricity, PV: Photovoltaic cell and ESS: Electricity storage system.

Fig. 6 Changes in electricity supply-demand in the smart community and changes in economics by the installed PV capacity in the commercial sector

introducing smart facilities, especially the electricity storage system is too large.

The introduction of the electricity storage system only is not largely contributed to improve the economics

of smart community connecting the commercial and residential sectors, as shown in Figs. 5 and 6. The introduction of the photovoltaic cell can improve the economics of smart community connecting the commercial and residential sectors, but as the scale of the electricity storage system becomes larger, the economics of smart community connecting the commercial and residential sectors becomes worse, also as shown in Figs. 5 and 6.

(3) Changes in economics of smart community under various prices changes and cost improvements

Figure 7 shows differences in payback years caused by changing various conditions such as electricity charge, FIT price, PV cost and ESS (electricity storage system) cost. For the improvement of economics in the smart community, the differences of electricity charge among peak, day and night time and the cost reduction of smart facilities such as PV and ESS are quite important. As compared with these factors, the influence of FIT price change is not so large, as shown in Fig. 7

Conclusions

The electricity storage system has the largest problem of economics in the smart community connecting the commercial and residential sectors. Under the present cost conditions on the electricity storage system, total economics of smart community connecting the commercial and residential sectors become worse, as the size of electricity storage system becomes larger.

For the sake of expanding smart community connecting the commercial and residential sectors, the cost reduction of smart facilities such as photovoltaic cell and electricity storage system is quite important as a future subject. Of these, the cost reduction of the electricity storage system would play an essential role particularly from the viewpoint of technology innovation.

It is quite essential to strengthen peoples' incentives to the introduction of smart community connecting the commercial and residential sectors from the viewpoints of policy. It is also required to look the role of FIT system over more carefully. The smart community connecting the commercial and residential sectors would be expected to influence to peoples' life style in the future.

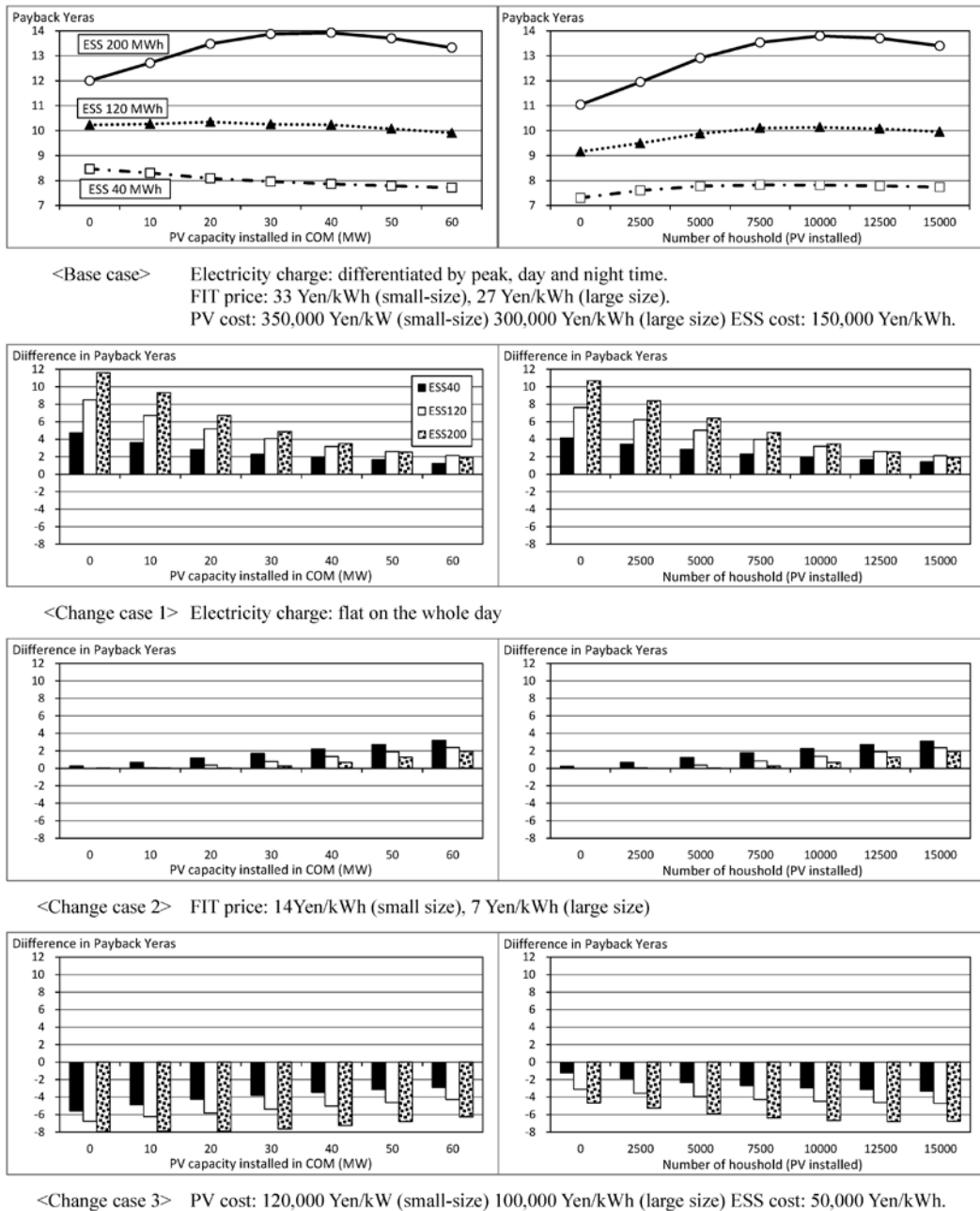


Fig. 7 Differences in payback years by changing various conditions and changes in economics

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